Future Tends in Systems & Software Engineering

- How Future Trends Bode Well for Systems Engineering's Partnership in the Transformation

Second Annual Systems Engineering Conference
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National Reconnaissance Office
Chantilly, Virginia
Theme: Systems Engineering: A Partner in Transformation

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Software Engineering Institute | Carnegie Mellon

Report Documentation Page

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The Software Engineering Institute - Improving the State of Practice of Engineering: Create, Apply and Amplify

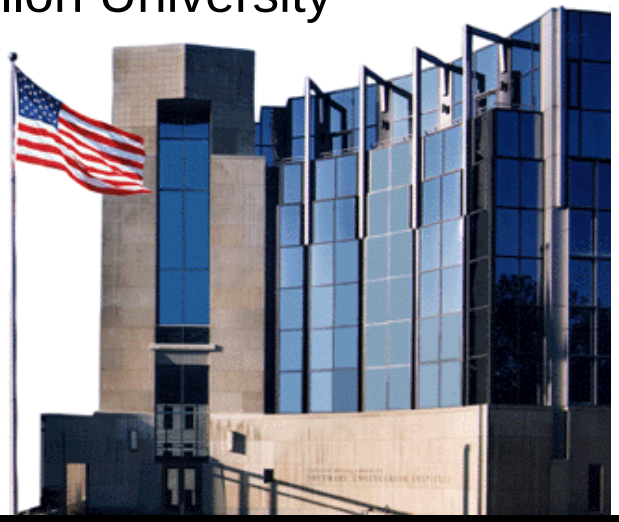
Federally Funded Research and Development Center

Created in 1984

Sponsored by the U.S. Department of Defense

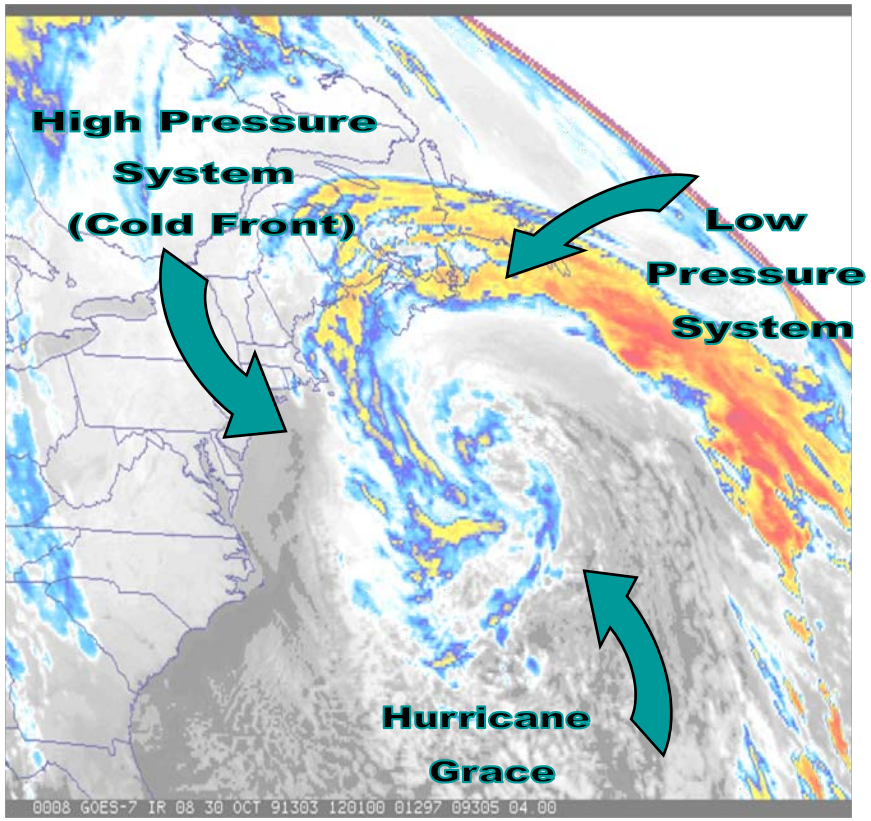
Locations in Pittsburgh, PA; Washington, DC; Frankfurt, Germany

Operated by Carnegie Mellon University



Overview

- **Transformational Trends in Systems and Software Engineering**
  - Development
  - Innovation
  - Integration
  - Human Element
  - Communications
  - Process
- **Ten Trends**
- **Wrap-up**



"Perfect Storm" Event, October 1991
National Oceanic & Atmospheric Administration

Development Challenges: Need for Space, Air, Ground, Water, Underwater Software-Intensive Systems that are Interconnected

- Several million SLOC programs; “Hybrid” systems combining legacy re-use, COTS, new development
- Multi-contractor teams using different processes; dispersed engineering, development & operational locations
- New technologies create opportunities/challenges; products change/evolve, corporations mutate
- Business/operational needs change - often faster than full system capability can be implemented
- Skillset Shortfalls; Cost and schedule constraints
- Demands for increased integration, interoperability, system of system capabilities
- Enterprise perspectives/requirements; sustainment concerns

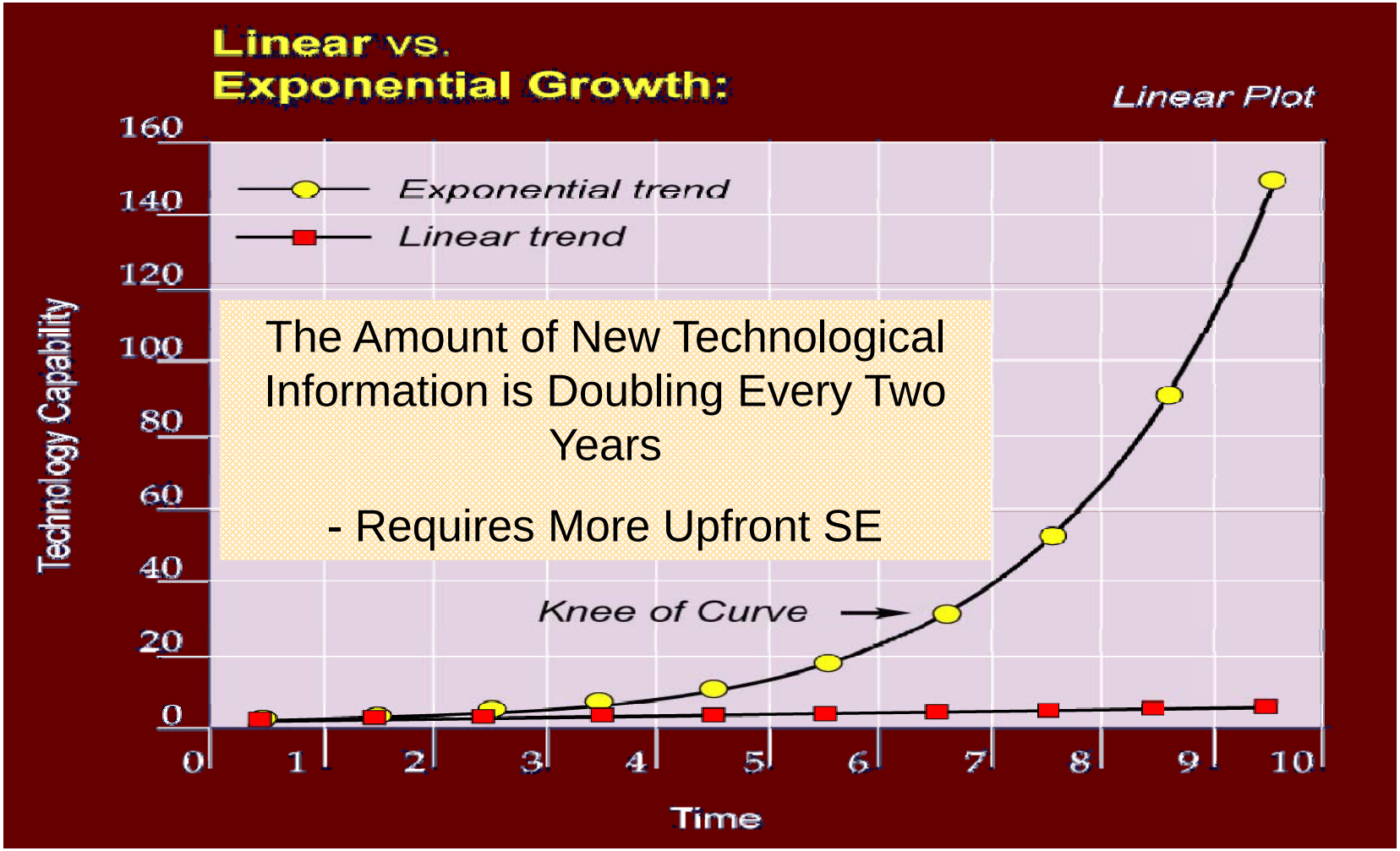
Systems Engineering – A Partner in Developing More Responsive Space Systems

Software Engineering Development Trends That Impact Systems Engineering

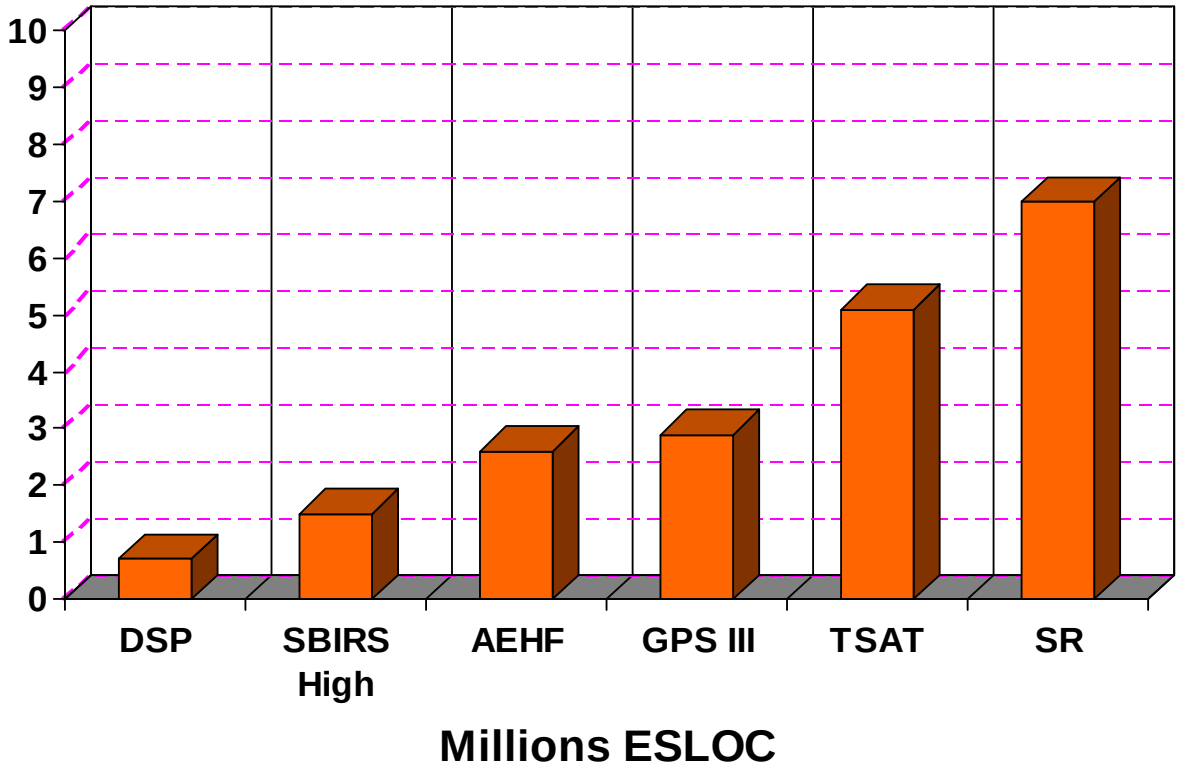
Traditional	Future
• Standalone systems	• Everything connected-maybe
• Mostly source code	• Mostly COTS components
• Requirements-driven	• Requirements are emergent
• Control over evolution	• Limited control over COTS evolution
• Focus on software	• Focus on systems and software
• Stable requirements	• Rapid change
• Premium on cost	• Premium on value, speed, quality
• Staffing workable	• Scarcity of critical talent

Emerging Dynamics of Bringing Systems and Software Engineering in Continued Partnership

The Acceleration of Innovation in the 21st Century: Impact Systems Engineering Transformational Activities

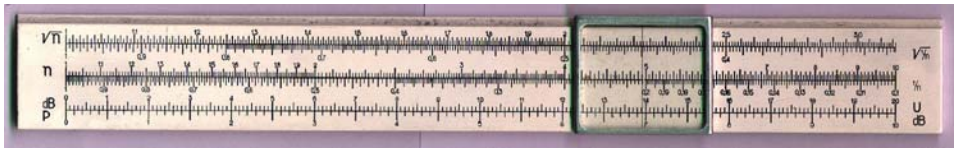


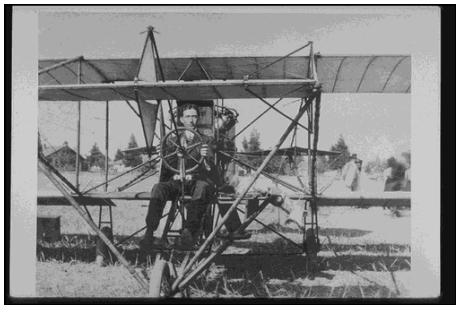
Growth Trend in Space System Software
(Onboard and Ground Software)



System/Software Engineering I/F Challenges: Augustine's Law – Growth of Software - Order of Magnitude Every 10 Years

In The Beginning





1960's

F-4A
1000
LOC

1970's

F-15A
50,000
LOC

1980's

F-16C
300K
LOC

1990's

F-22
1.7M
LOC

2000+

F-35
>6M
LOC

System/Software I/F Challenges: Relationship Between Complexity and Acquisition Success Improving But Not Enough!

Software is Growing in Complexity

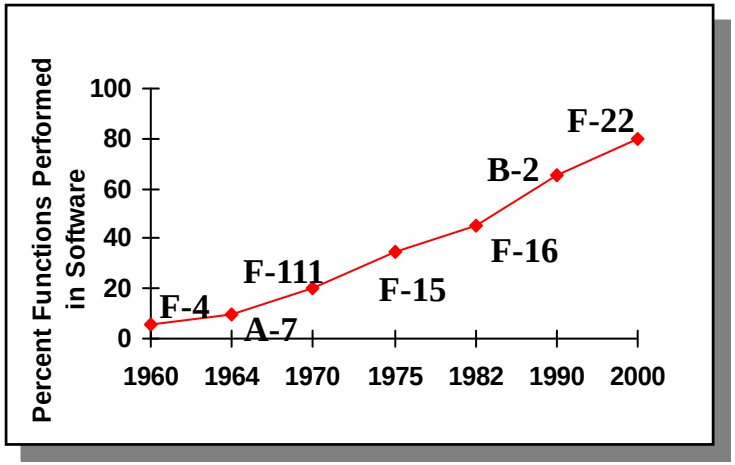
- 80% of some weapon system functionality is dependent upon software[1]
- Consequences of software failure can be catastrophic

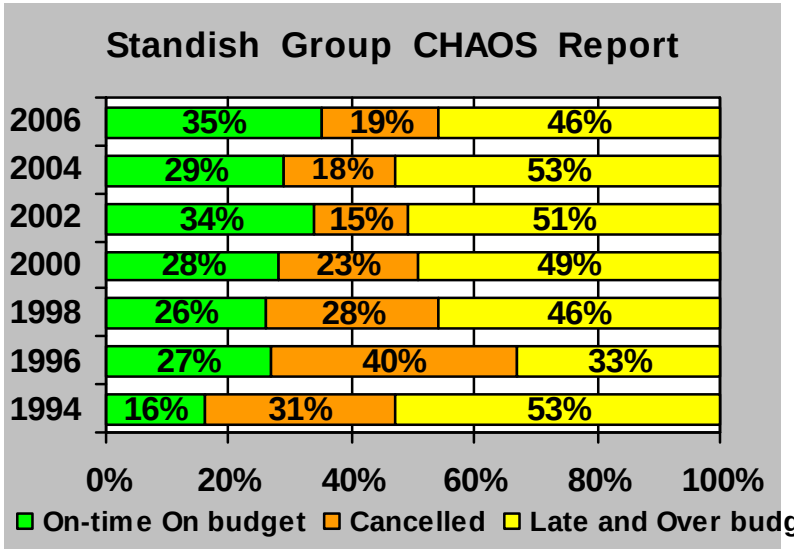
Software Acquisition is Difficult

- 46% are over-budget (by an average of 47%) or late (by an average of 72%)[2]
- "Successful projects" have 68% of specified features[2]

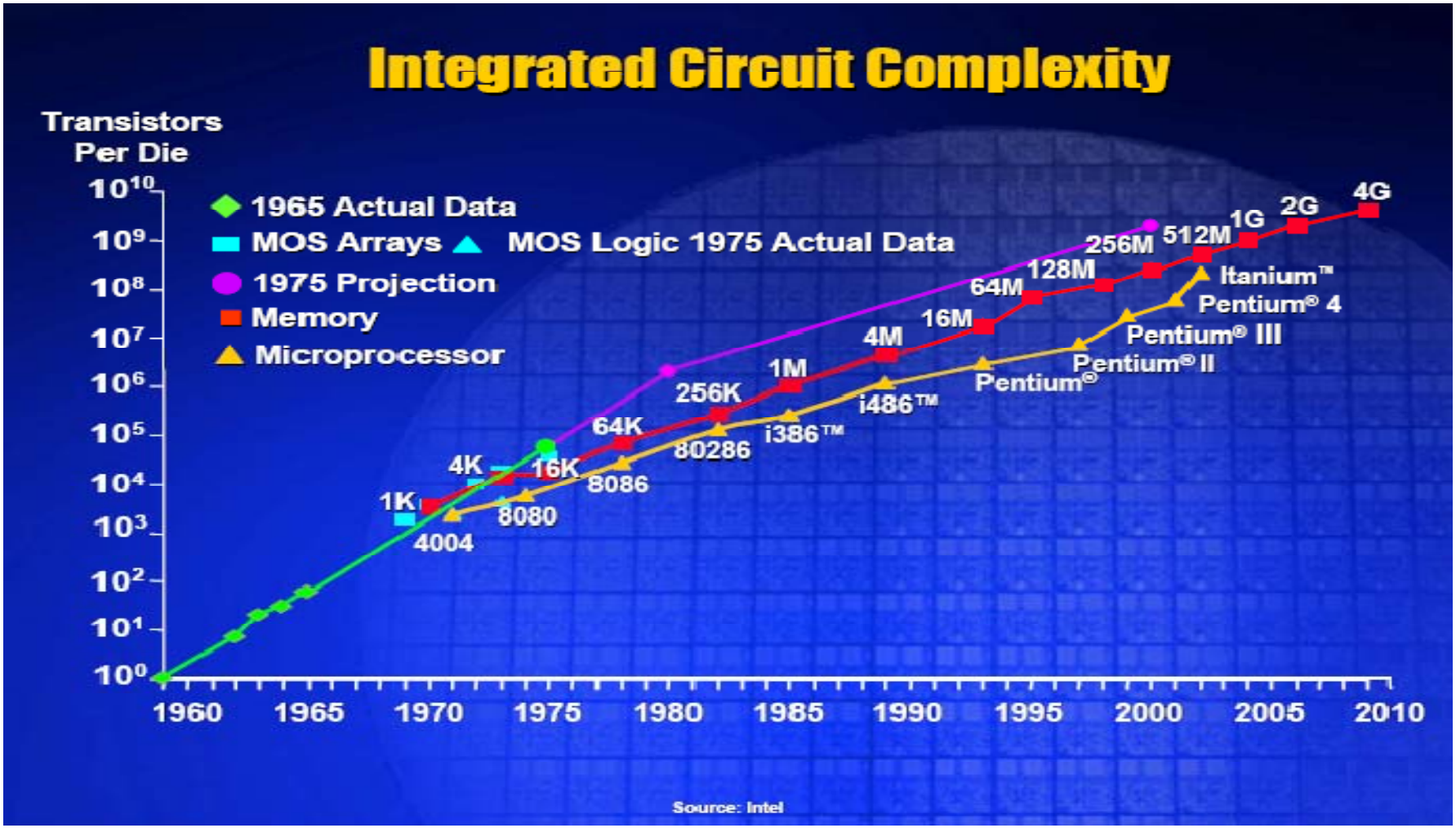
Software is Pervasive

- Space, IT Systems, C4ISR, Weapons, etc





System/Hardware Engineering I/F Challenges - Moore's Law: The Number of Transistors That Can be Placed on an Integrated Circuit is Doubling Approximately Every Two Years



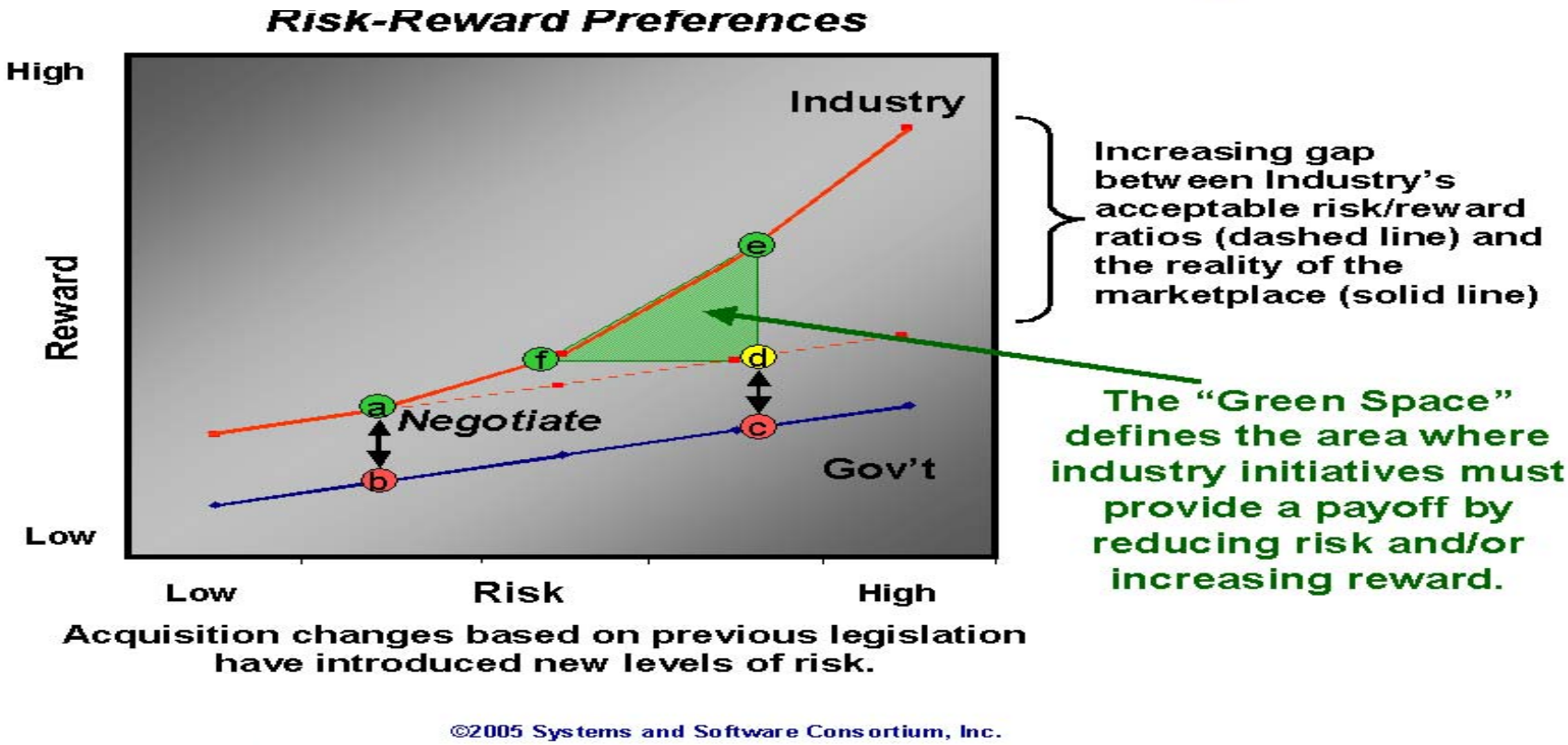
Systems Engineering Integration Challenges: Some Drivers That Increase the Complexity of Acquiring Systems

Platform	*Customer Emphasis*	Enterprise
Requirements	*Acquisition Model*	Capabilities
Dominant Customer	*Program Execution*	Collaboration
"Boxes"	*Integration Challenge*	"Layers & Stacks"
Proprietary	*Architectures and Standards*	Plug & Play

Transformation will require addressing both sides, and do so with compressed delivery schedules via improvements in systems/software engineering

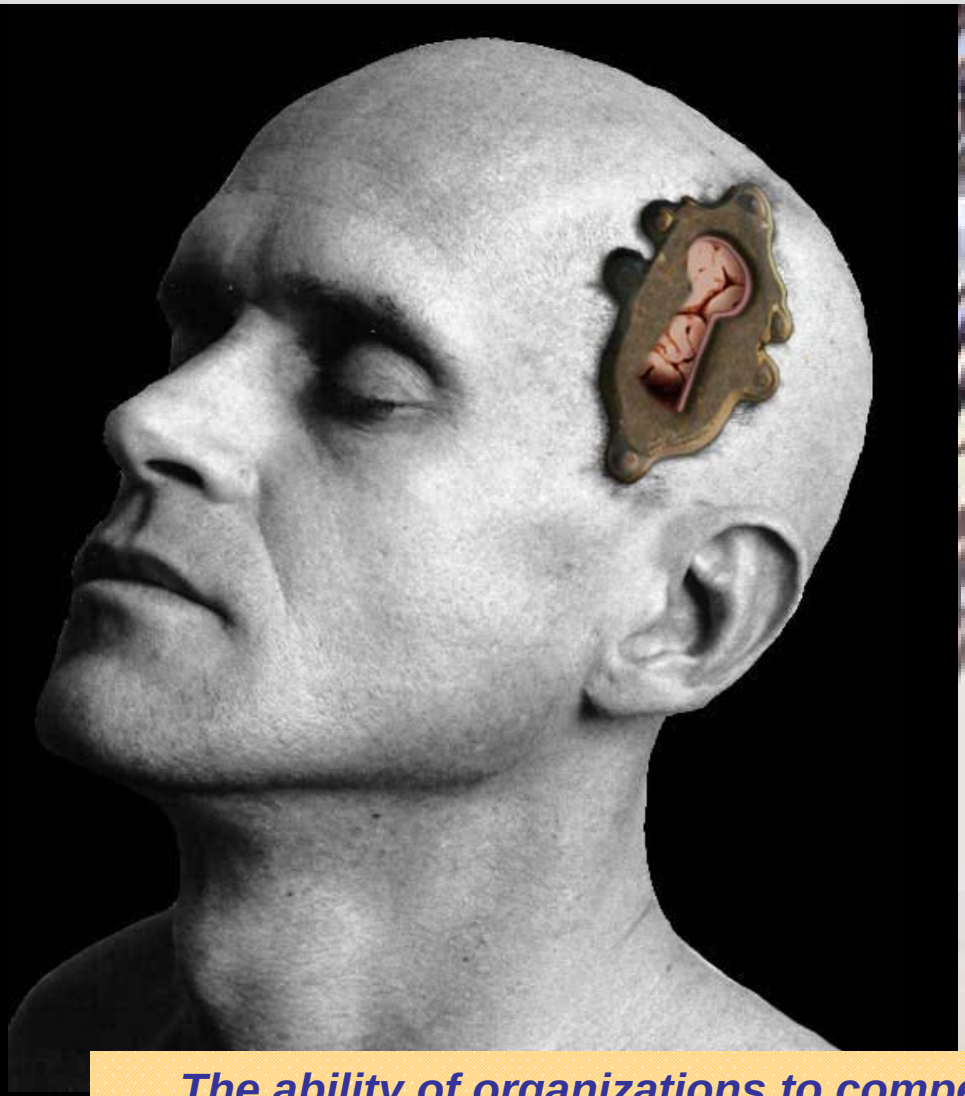
Increased Reliance on Acquirer/Developer to Reduce Integration Risk by Effectively Navigating the Green/Acquisition Space

Navigating the "Green Space"



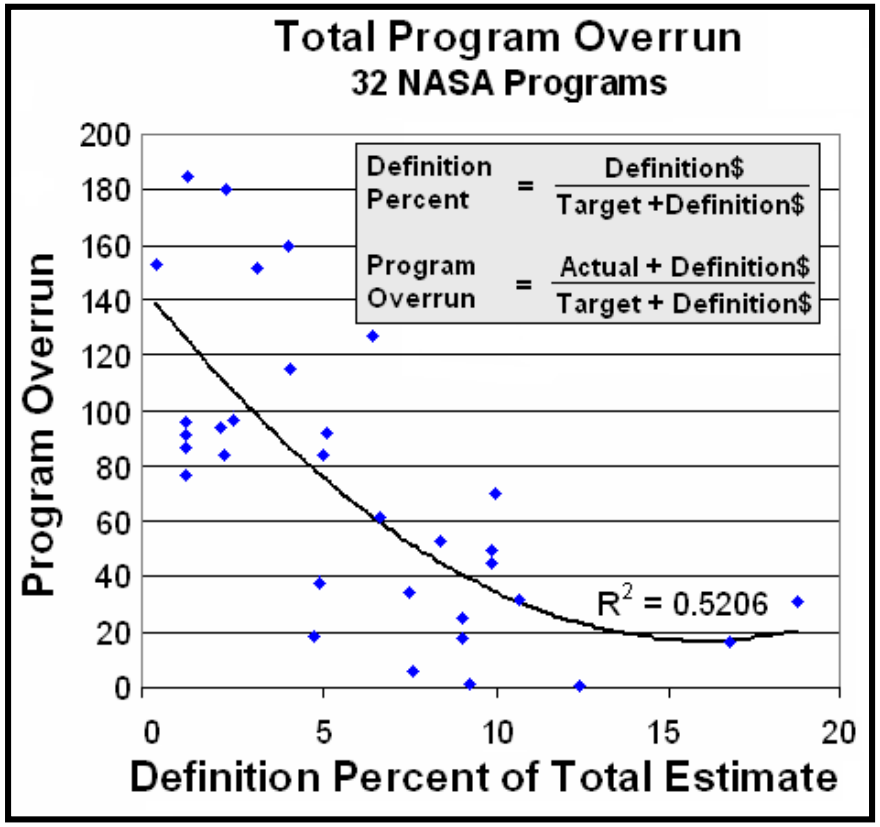
Source: Nidiffer and Dolan, IEEE Software, Sept/Oct 2005

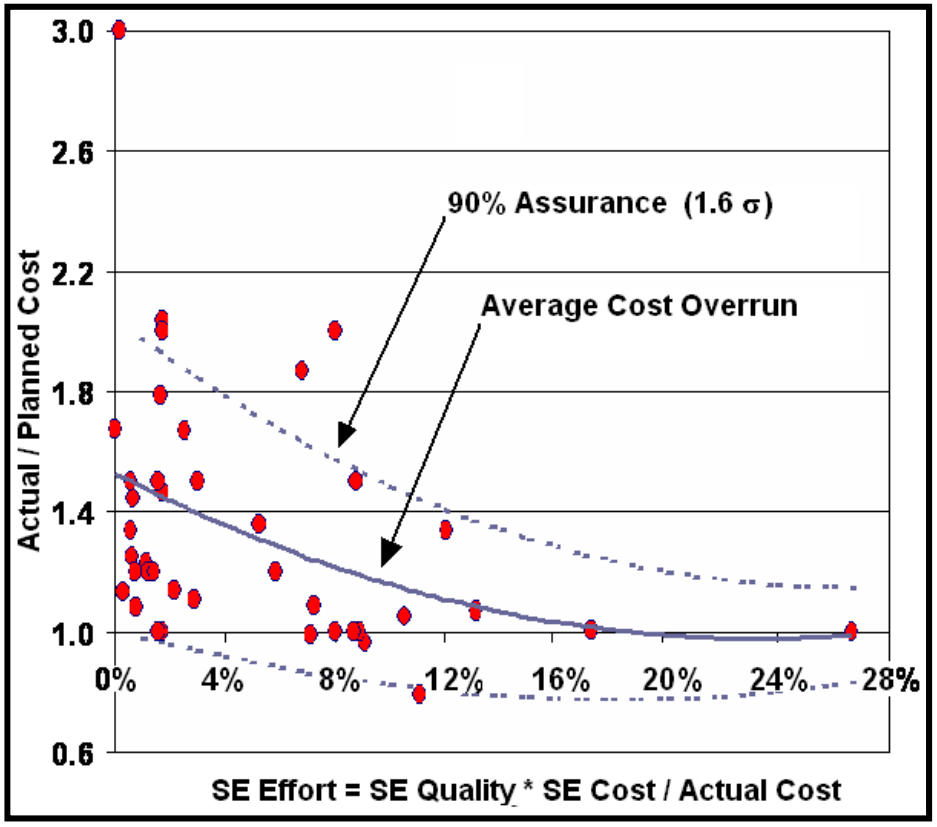
Human Element – Perhaps the Longest Pole in the Tent
Is Rebuilding the Workforce – Gen Thomas S. Moorman Jr. (Ret)
March 2008



The ability of organizations to compete will increasing depend on the innovation of the human element

The Challenge - Supporting Evidence





Gruhl, Werner (1992), Lessons Learned: Cost/Schedule Assessment, Internal Presentation, NASA Comptroller's Office

Honour, Eric (2004), *Understanding the Value of Systems Engineering*, Proceedings of the 14th Annual INCOSE International Symposium

Systems Engineering Effectiveness Survey (2004-2007)

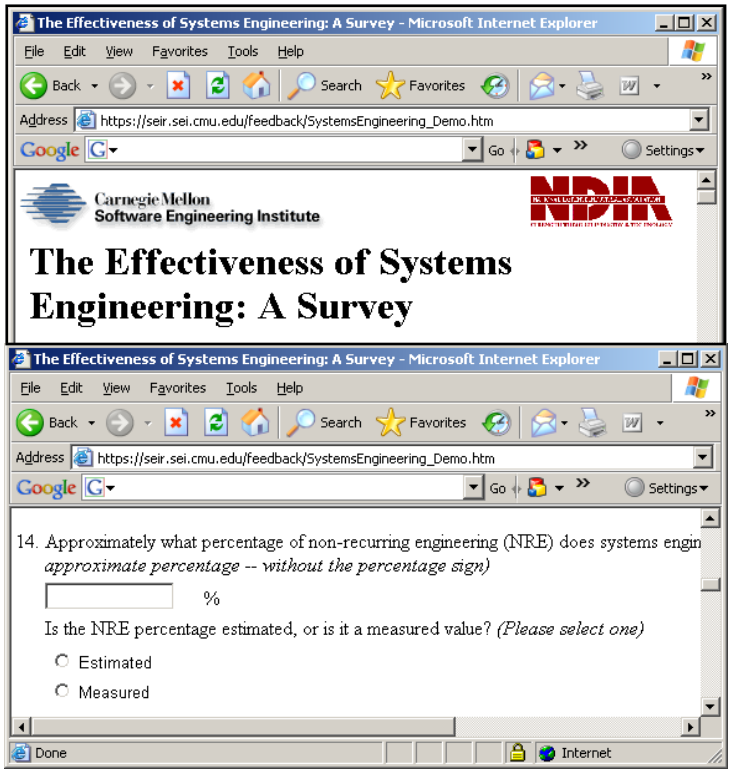
Hypothesis: **The effective performance of SE best practices on a development program yields quantifiable improvements in the program execution (e.g., improved cost performance, schedule performance, technical performance).**

Objectives:

- Characterize effective SE practices
- Correlate SE practices with measures of program performance

Approach:

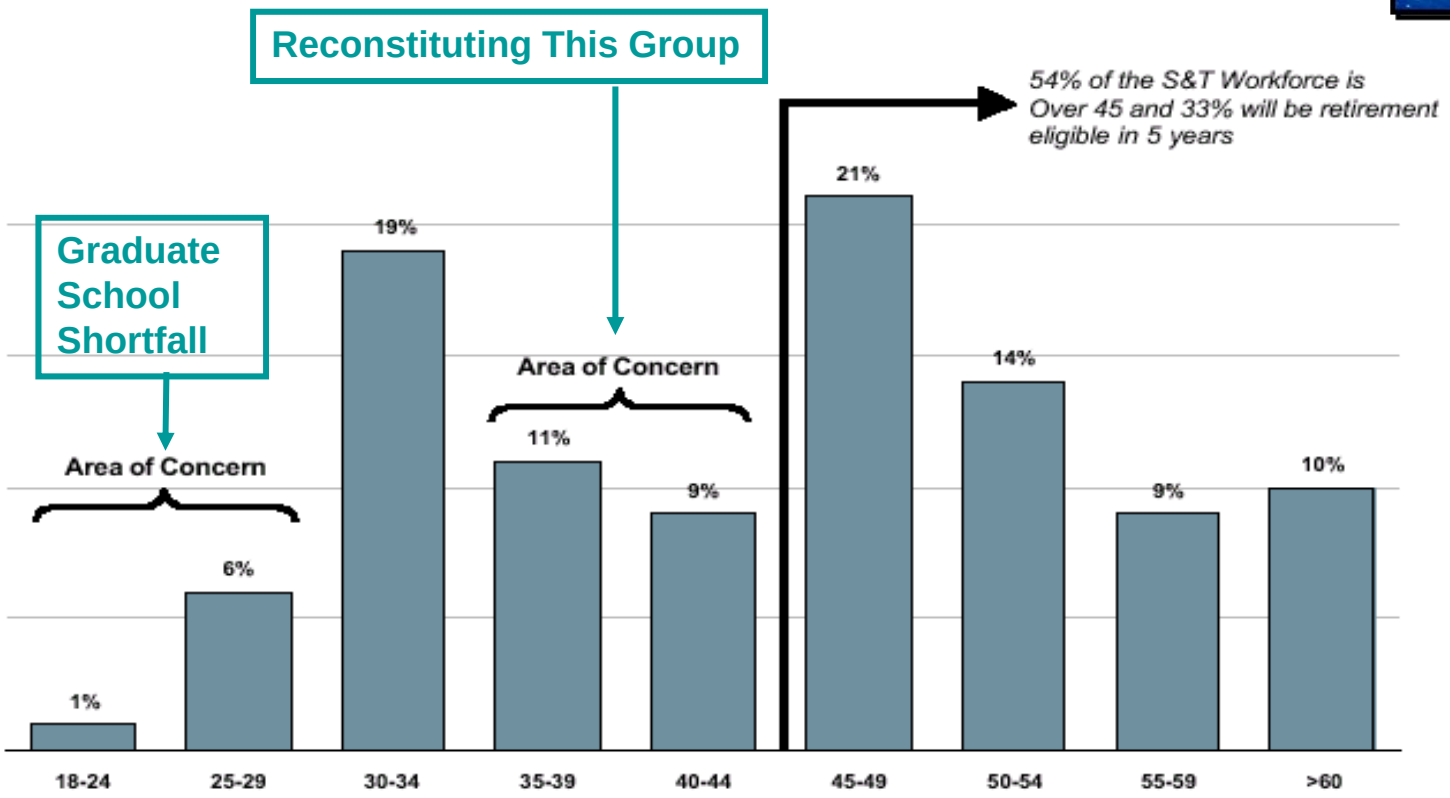
- Distribute survey to NDIA companies
- SEI analysis and correlation of responses



Survey Areas:

Process definition
Project planning
Risk management
Requirements development
Requirements management
Trade studies
Interfaces
Product structure
Product integration
Test and verification
Configuration mgmt
Metrics

Society Drivers: Bimodal Demographics (Space Industry)

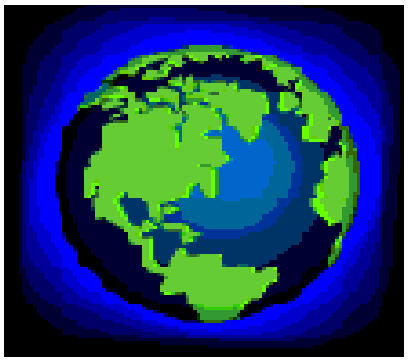


Average Space Industry S&E Workforce Age Distribution

Trend: Industry/Gov't Will Increasingly Focus on Attracting, Training and Retaining Systems Engineering Talent

Source: Lockheed Martin (0004305-001: AIAA SE Workforce Data. Frank Cappuccio VP & GM Skunk Works)

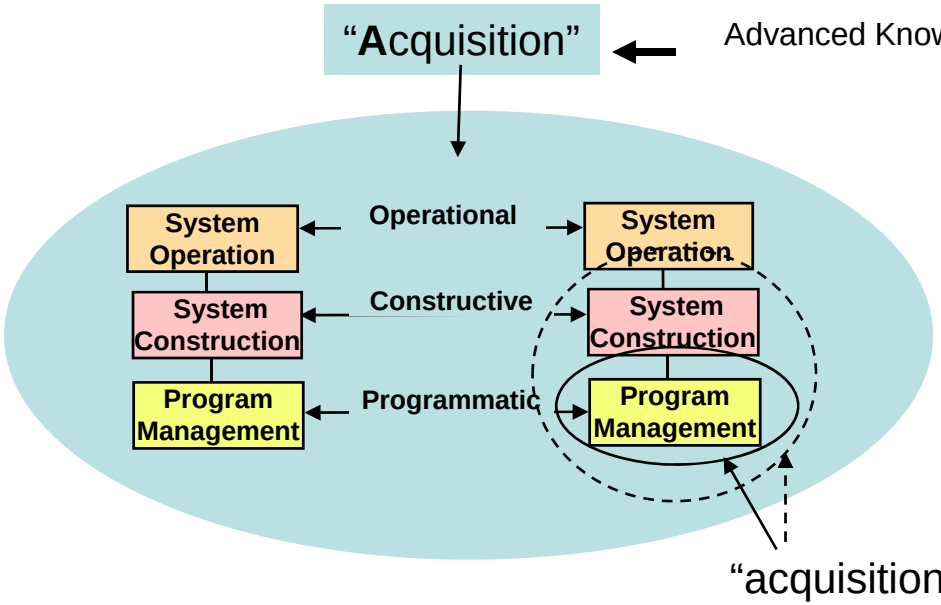
Organizational Performance - Flexible Boundary-Crossing Acquisition Structure

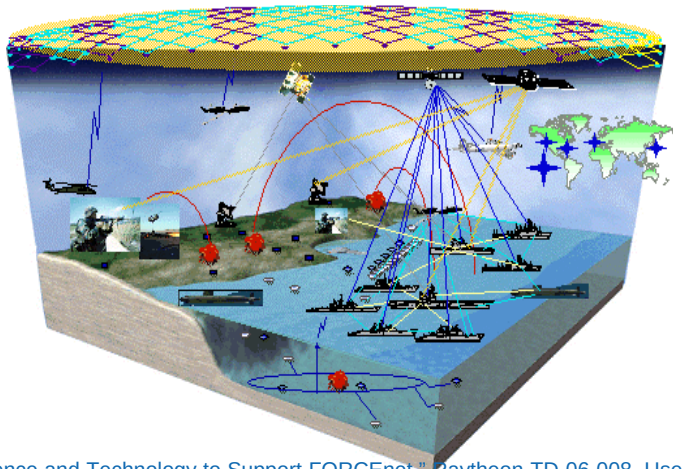


2005 study confirmed*:

- In advanced knowledge-based organizations, management's desire for the flow of knowledge is greater than the desire to control boundaries
- Unlike the matrix organization, there is less impact on the dynamics of formal power and control

* Using Communities of Practice to Drive Organizational Performance and Innovation, 2005, APQ study





From "Science and Technology to Support FORCEnet," Raytheon TD-06-008. Used by permission.

Ref: Jim Smith, (703) 908-8221,jds@sei.cmu.edu

Human Element Challenge: Bumpy Road at the Systems Engineering/Software Engineering Intersection

Whole System → **Parts of System**
Contradiction in Focus/Optimizing

Long Time → **Rapid**
Contradiction in Cycle Time

Circular Causality → **Linear Causality**
Contradiction in Design Dependency

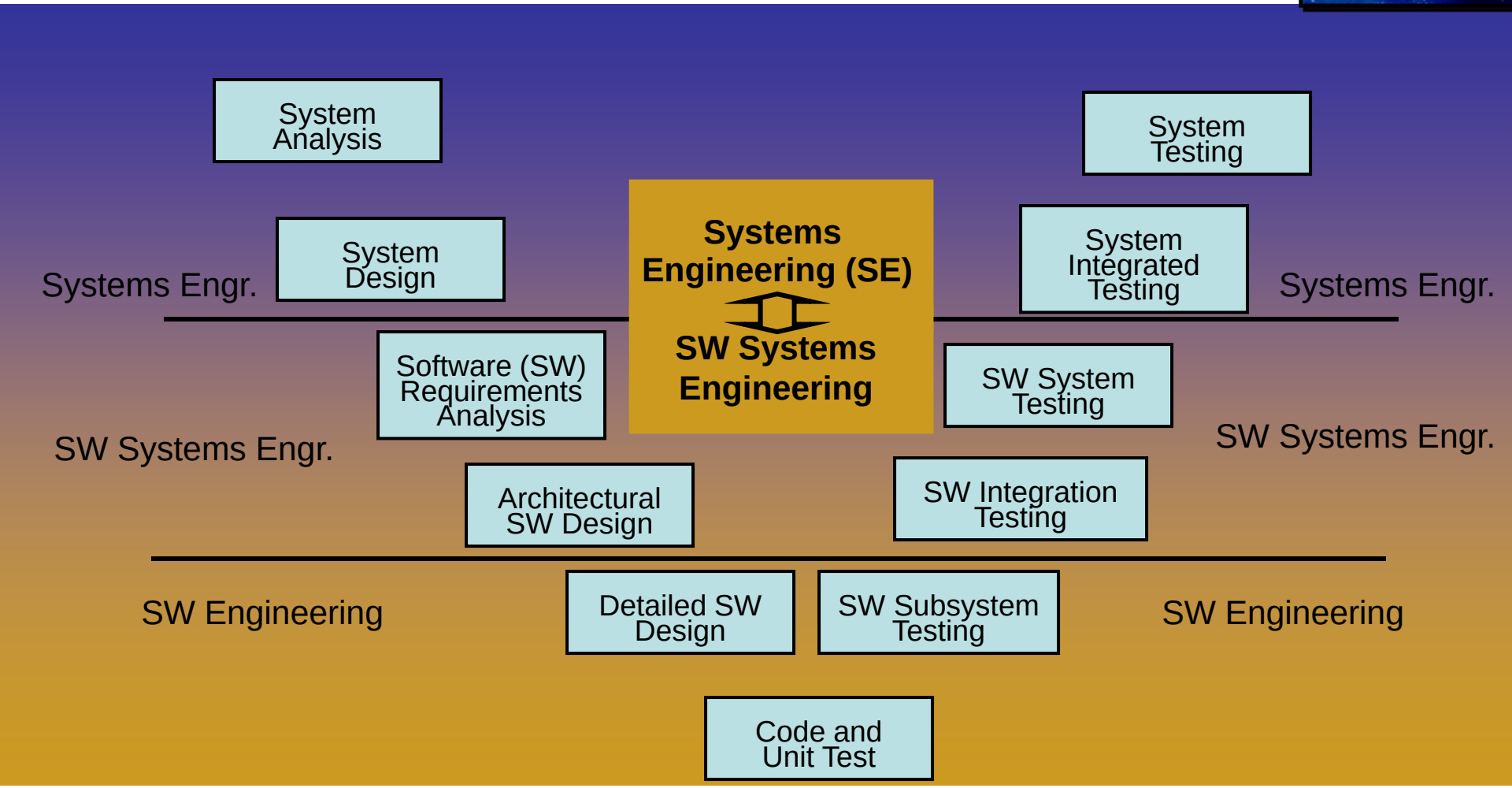
Systematic → **Art**
Contradiction in Spirit

Generalist → **Wants Detail**
Contradiction in Detail

The Integration of Systems and Software Engineering will take SE Leadership Commitment

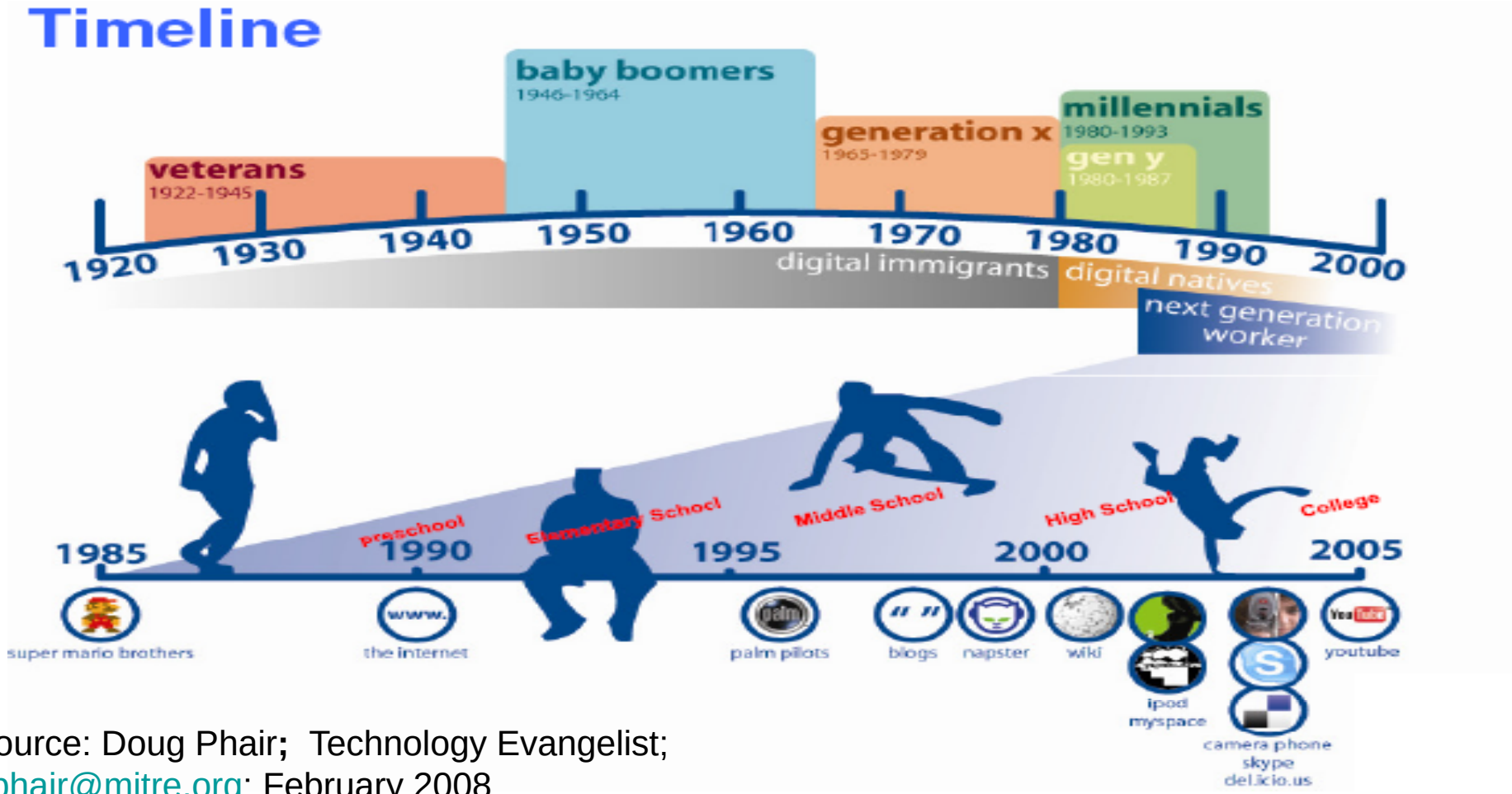
Source: Kurstedt, Harold, Newport Group, 2008

Human Element: Current Objective is for Software and Systems Engineering to Become More Integrated Versus Separated



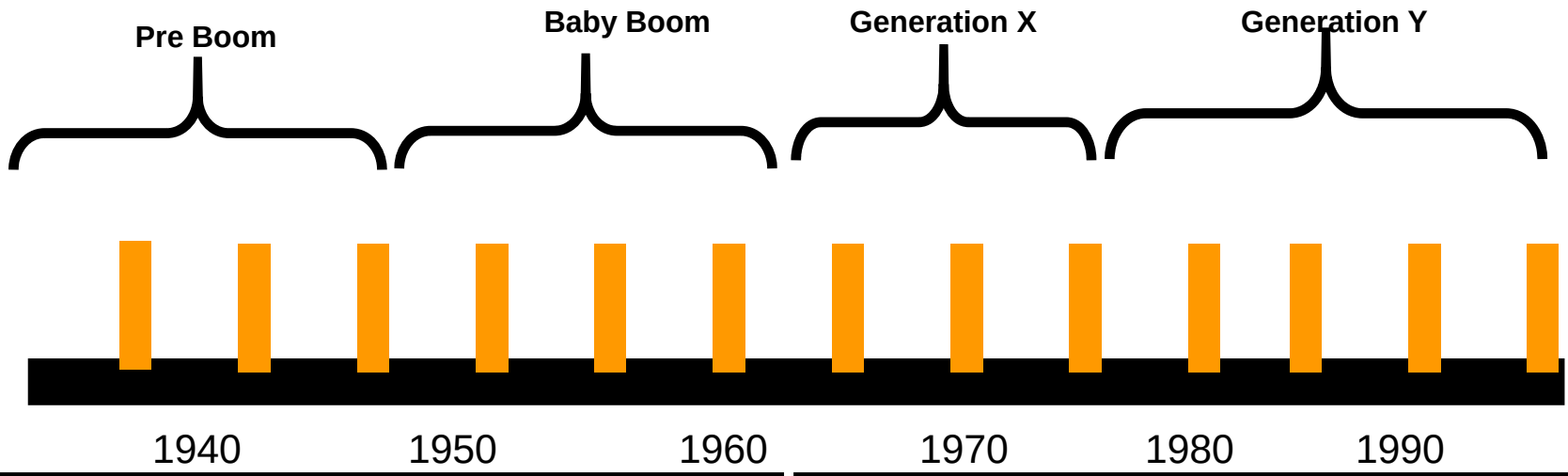
OSD Initiative: Integrated Software and Systems Engineering Curriculum

Human Element in the Work-Space Environment



Source: Doug Phair; Technology Evangelist; dphair@mitre.org; February 2008

Human Element: More Generation Y Workers Will Enter the Workplace



Generation Y Characteristics

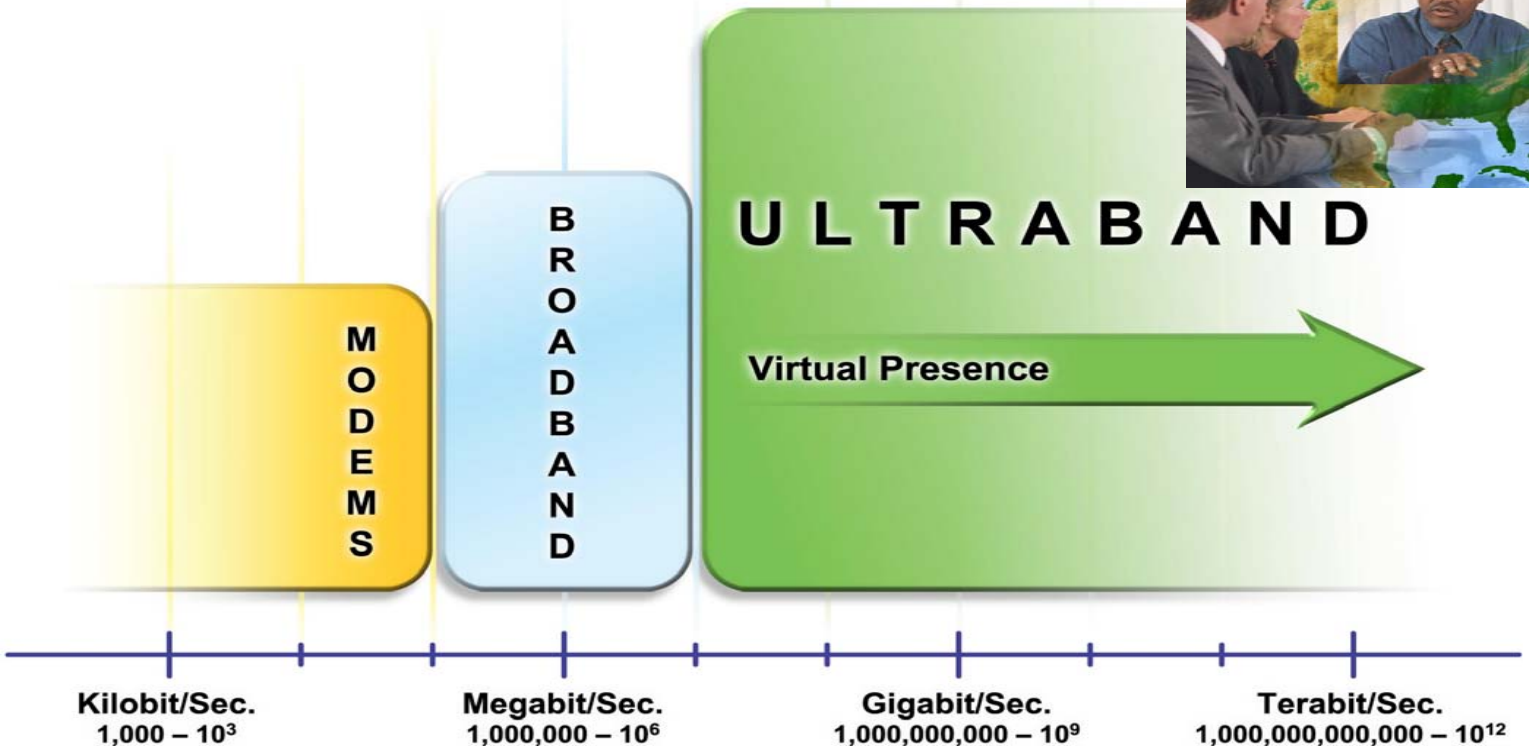
- Born late 1970s to mid-1990s
- Larger than Generation X
- More ethnically diverse
- Technologically savvy

What Makes Generation Y Tick

- High Expectation of Employers
- Goals, Goals, Goals
- Desire for Immediate Responsibility
- Balance and Flexibility

Source: Cara Spiro, DAU, 2006

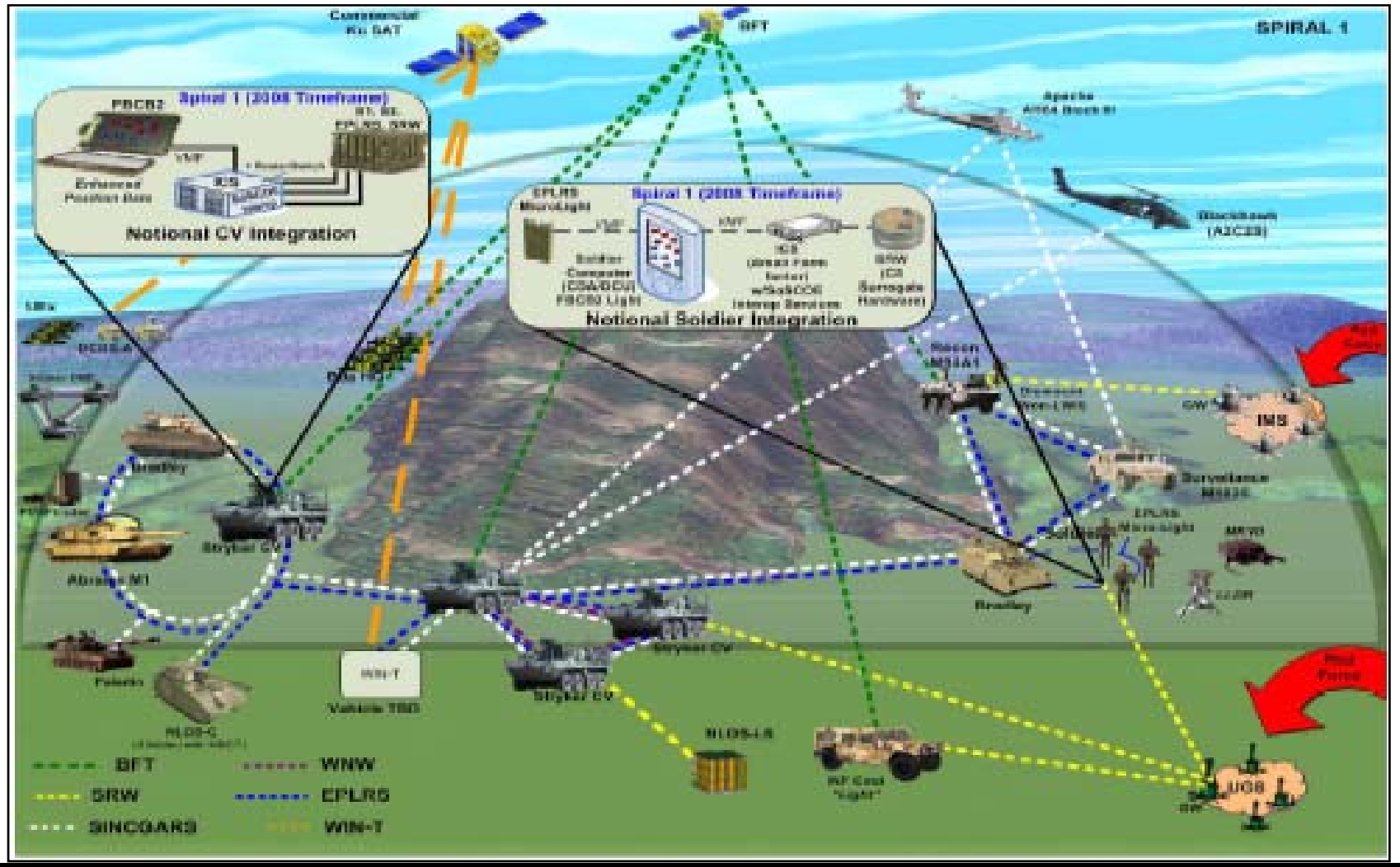
Increased Capabilities in the Digital Spectrum Enables SE Improvements in Communication and Collaboration



Rule #4: The best companies are the best collaborators*

*** Friedman, Thomas L. "*The World Is Flat*", Farrar, Straus and Giroux, 2005**

Communications Among Systems – Fostering a Growing Interdependence and Integration



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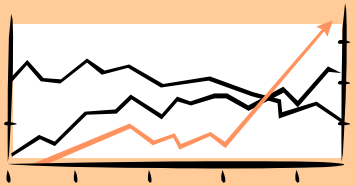
SE is a Partner in Addressing Both Approaches to Process Improvement

Data-Driven (e.g., Six Sigma, Lean)



Clarify what your customer wants (Voice of Customer)

- Critical to Quality (CTQs)

Determine what your processes can do (Voice of Process)

- Statistical Process Control

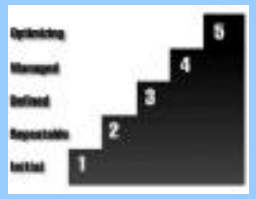
Identify and prioritize improvement opportunities

- Causal analysis of data

Determine where your customers/competitors are going (Voice of Business)

- Design for Six Sigma

Model-Driven (e.g., CMM, CMMI)



Determine the industry best practice

- Benchmarking, models

Compare your current practices to the model

- Appraisal, education

Identify and prioritize improvement opportunities

- Implementation
- Institutionalization

Look for ways to optimize the processes

Systems and Software Engineering: Ten Trends

- *Greater demands on systems and software engineers will stimulate growth in the field – nationally and internationally*
- *Industry/Gov't will increasingly focus on attracting, training and retaining systems and software engineering talent – short and long run – with emphasis on providing a Generation Y work environment*
- *Increased reliance on systems and software engineering processes and technologies to effectively manage the acquisition/"green" space*
- *The laws of Augustine's and Moore will continue to hold and will continue to be a forcing function to bring the fields of software and systems engineering closer together*
- *Improvements risk-reduction collaboration mechanisms will be significant enablers for increases in systems and software engineering communication and "decision velocity"*

Systems and Software Engineering: Ten Trends

- *Increased need for a large number of complex systems and systems of systems will lead to investments in research and technology*
- *Systems and software engineers will continually find way to innovative to reduce complexity*
  - *Increased importance of modeling and simulation*
  - *Increased reliance on architectures (top-down and bottoms-up)*
  - *Increased design for continuous evolution and deployment at all levels will occur*
- *Increased customer requests for system and software engineering support will occur earlier in life cycle*
- *Shift of systems and software engineering focus from the platform to the networks and ground systems*
- *Process improvement will continue to be important*

Questions?

THE
KNOWN WORLD
Beyond here there be Dragons

Recommended Readings

Buckman, Robert H. *Building a Knowledge-Driven Organization.* McGraw-Hill, New York, NY, 2004.

GAO Report: 08-467SP, Defense Acquisitions – Assessment of Selected Weapon Systems, March 2008

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Wladawsky-Berger, Irving. "The Future of IT in an On-Demand World." IBM Server Group, Keynote address at OSBC 2005. Archived at http://www.itconversations.com/shows/detail495.html